

# Optical Oceanography at Friday Harbor Laboratories

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## LONG-TERM GOAL

Our long-term scientific goals are to contribute to the understanding of the optical variability of phytoplankton and to the understanding of radiative transfer in the ocean. The educational corollary of our long-term goals is to educate a cadre of students who will have synthesized a perspective of the field that will allow them “to make a difference” in optical oceanography.

## OBJECTIVES

The objective of this project was to offer an advanced graduate course in optical oceanography that combined in-water and above-water measurement, theory, and models.

## APPROACH

The course was taught between 20 July to 22 August 1998 at the University of Washington's Friday Harbor Laboratories on San Juan Island, Washington State. The course integrated measurement, theory, and models to study underwater and remotely-sensed spectral light fields. Course elements included lectures, critical discussions of key papers and concepts, directed laboratories, methods of data analysis, a field sampling program, data assimilation into models, round-table discussions, and collaborative and individual student projects. A special emphasis in summer 1998 was on the integration of in-water optics with hyperspectral aircraft remote sensing of the optically-diverse Case II waters surrounding the San Juan Islands of Washington State. Students had the opportunity to measure spectral radiance, irradiance, water-leaving radiance, absorption and scattering coefficients, and other optical properties in conjunction with a series of aircraft remote-sensing overflights.

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## WORK COMPLETED

### *Lectures:*

Thirty lectures were given; topics covered in the lectures included: the nature of light; radiometric terms; underlying principles and limitations of current radiometric measurements; optical properties of water including inherent and apparent optical properties; role of water, phytoplankton, dissolved organic material, and other biogenic and terrigenous particles in determining inherent optical properties; measurement of inherent optical properties; derivation of the radiative transfer equations; relationship between inherent and apparent optical properties; remote sensing theory and application; inverse methods, including retrieval of phytoplankton properties and effects of fluorescence in remote sensing; air-water interface effects; Monte Carlo and eigenmatrix methods, etc.

### *Critical discussions of key papers:*

One of the components of the FHL course that really made this course such a valuable learning experience for the students was the discussion of papers. Saturdays were devoted to in-depth discussions of key papers. These half-day or longer discussions followed a proven formula, called "Learning Through Discussion," that crystallized the students' integration of information.

### *Formal exercises:*

During the first two weeks the students participated in formal (i.e., instructor-directed) laboratory, field, and modeling exercises, with an emphasis on integration of measurements with models and theory. The first week focused on absorption measurements; the second on scattering measurements. The class was divided into small groups and worked with an instructor on a specific measurement. We relied heavily on "cooperative learning." During the first two weeks, the students had opportunities to work with most of the state-of-the-art instrumentation in optical oceanography; we relied heavily on instruments that belonged either to one of the instructors or were "loaners" from optical instrument companies. This phase of the course prepared the students for the intensive field-sampling component during the third week.

### *Modeling:*

We were able to provide one computer per student and each computer was capable of running Curt Mobley's Hydrolight model. Students greatly benefited from the ability to "predict" apparent optical properties from inherent optical properties. Any disagreements between observations and predictions lead to valuable learning experiences. Mie scattering models were also used in conjunction with particle size analyses.

### *Aircraft remote sensing experiment:*

During week III, the students participated in a three-day field experiment with three boats and aircraft overflights. The aircraft carried the NRL Portable Hyperspectral Imager for Low Light Spectroscopy (PHILLS). The students made in-water measurements in East Sound and West Sound (Orcas Island) and the Strait of Juan de Fuca. These water bodies represented significantly different Case II water types. The measurements collected constituted the data for the student projects and the processed data are currently posted on the class web site.

### *Student projects:*

During weeks IV and V, the students worked collaboratively to process the field data, assess it for quality, and post it on the class server. As individuals, each student used the common data base to focus on a specific question. At the end of the class, each student presented an oral report. Fourteen out of the fifteen students will present posters at the 1999 ASLO meeting in Santa Fe on their class projects in a special session dedicated to the educational achievements of the FHL Optical Oceanography .

## **RESULTS**

In the 1998 summer course we had the opportunity to educate 15 students in an advanced graduate course in optical oceanography that combined in-water and above-water measurement, theory, and models. These young women and men all came from outstanding research groups at other institutions. In this five-week course we offered a comprehensive perspective of optical oceanography that allowed these students to fill in gaps in their knowledge. By creating a supportive learning environment we were able to facilitate learning and integration of new information with existing knowledge.

At the 1999 ASLO meeting in Santa Fe fourteen out of the fifteen students will present posters in a special session dedicated to the educational achievements of the FHL Optical Oceanography course. The corrected, calibrated data collected during the three-day field program is currently posted on the class web site.

## **IMPACTS**

This course serves three important impacts. Firstly, the course provides a valuable dimension in the education of the next generation of optical oceanographers. (N.B.: the 1998 course is the fifth offering of Optical Oceanography at the UW's Friday Harbor Laboratories. Since 1985 we

have had the opportunity to educate 65 students.) Secondly, the knowledge and experience the students gained in this course directly benefits their advisors, most of whom are ONR-sponsored investigators. Thirdly, because some of the students are non-U.S. students, international connections that could prove valuable in the future are established.

## **TRANSITIONS**

The knowledge and experience the students gained in this course directly benefits their advisors, most of whom are ONR-sponsored investigators.

## **RELATED PROJECTS**

The ONR-sponsored research projects of Dr. Curtiss Davis (NRL), Dr. Alan Weidemann (NRL), and Dr. Robert Maffione (HOBI Labs) greatly benefited the course. These individuals agreed to carry out some of their field work at FHL during the period of the course. They very generously allowed the students to participate in data collection and analysis. These related projects augmented the learning experience for the students.

## **REFERENCES**

At the ASLO meeting in Santa Fe in February 1999, a total of nineteen posters will be presented in a special session dedicated to the educational achievements of the FHL Optical Oceanography course.

The address for the course web site is

<http://www.ocean.washington.edu/courses/oc590>